Appendix A
Technical Analysis Methodologies and Policies

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The following section outlines the methodology and analysis parameters used to quantify the measures of effectiveness on study intersections for the analysis scenarios.

Level of Service Methodologies

Traffic operations are quantified through the determination of "Level of Service" (LOS). Level of service is a qualitative measure of traffic operating conditions, whereby a letter grade "A" through "F" is assigned to an intersection, representing progressively worsening traffic operations as determined by vehicle delay or congestion. LOS “A” represents free-flow operating conditions and LOS “F” represents over-capacity conditions. Levels of Service were calculated for all study intersection control types using the methods documented in the Transportation Research Board Publication *Highway Capacity Manual, Sixth Edition, A Guide for Multimodal Mobility Analysis, 2016* (HCM 6).

Intersection LOS Methodologies

Level of Service (LOS) was calculated for all intersection control types using the methods documented in the HCM 6. For a signalized or all-way stop-controlled (AWSC) intersection, an LOS determination is based on the calculated averaged delay for all approaches and movements. For a two-way or one-way (T-intersection) stop controlled (TWSC) intersection, an LOS determination is based upon the calculated average delay for all movements of the worst-performing approach. The Synchro 10 (Trafficware) software program was used to implement the HCM 6 and Synchro analysis methodologies. Synchro 10 has the capability to produce results using HCM 2000, HCM 2010, and HCM 6 methodologies, as well as Synchro methodology, and takes into account intersection signal timing and queuing constraints when calculating delay, the corresponding delay, and queue lengths. For intersections with channelized free right-turn movements which by-pass the intersection, HCM methodologies consider that vehicles using a free right turn movement will not contribute to vehicle delay at an intersection. The Synchro 10 outputs can be found in the Appendix. The vehicular delay-based LOS criteria for different types of intersection control are outlined in Table A.1.

Table A.1 Level of Service (LOS) Criteria for Intersections

Level of Service	Type of Flow	Delay	Maneuverability	Stopped Delay/Vehicle: Signalized	Stopped Delay/Vehicle: Un-signalized	Stopped Delay/Vehicle: All-Way Stop
A	Stable Flow	Very slight delay. Progression is very favorable, with most vehicles arriving during the green phase not stopping at all.	Turning movements are easily made, and nearly all drivers find freedom of operation.	<10.0	<10.0	<10.0
B	Stable Flow	Good progression and/or short cycle lengths. More vehicles stop than for LOS A, causing higher levels of average delay.	Vehicle platoons are formed. Many drivers begin to feel somewhat restricted within groups of vehicles.	>10.0 and <20.0	>10.0 and <15.0	>10.0 and <15.0
C	Stable Flow	Higher delays resulting from fair progression and/or longer cycle lengths. Individual cycle failures may begin to appear at this level. The number of vehicles stopping is significant, although many still pass through the intersection without stopping.	Back-ups may develop behind turning vehicles. Most drivers feel somewhat restricted	>20.0 and <35.0	>15.0 and <25.0	>15.0 and <25.0
D	Approaching Unstable Flow	The influence of congestion becomes more noticeable. Longer delays may result from some combination of unfavorable progression, long cycle lengths, or high volume-to-capacity ratios. Many vehicles stop, and the proportion of vehicles not stopping declines. Individual cycle failures are noticeable.	Maneuverability is severely limited during short periods due to temporary back-ups.	>35.0 and <55.0	>25.0 and <35.0	>25.0 and <35.0
E	Unstable Flow	Generally considered to be the limit of acceptable delay. Indicative of poor progression, long cycle lengths, and high volume-to-capacity ratios. Individual cycle failures are frequent occurrences.	There are typically long queues of vehicles waiting upstream of the intersection.	>55.0 and <80.0	>35.0 and <50.0	>35.0 and <50.0
F	Forced Flow	Generally considered to be unacceptable to most drivers. Often occurs with over saturation. May also occur at high volume-to-capacity ratios. There are many individual cycle failures. Poor progression and long cycle lengths may also be major contributing factors.	Jammed conditions. Back-ups from other locations restrict or prevent movement. Volumes may vary widely, depending principally on the downstream back-up conditions.	>80.0	>50.0	>50.0

Agency LOS Guidelines and Policies

City of Galt LOS Guidelines

The City of Galt 2030 General Plan contains the following Level of Service Policies pertinent to this study:

> **Policy C-1.3: Levels of Service:** *The City should develop and manage its roadway system to maintain LOS "E" on all streets and intersections within a quarter-mile of State Route 99, along A Street and C Street between State Route 99 to the railroad tracks, and along Lincoln Way between Pringle Avenue to Meladee Lane. The City should develop a LOS "D" or better on all other streets and intersections.*

Caltrans LOS Guidelines

Caltrans' Guide for the Preparation of Traffic Impact Studies contains the following policy pertaining to the LOS standards within Caltrans jurisdiction:

> *Caltrans endeavors to maintain a target LOS at the transition between LOS "C" and LOS "D" on State highway facilities, however, Caltrans acknowledges that this may not always be feasible and recommends that the lead agency consult with Caltrans to determine the appropriate target LOS.*

For the purpose of this study, the City's LOS criteria are applied for all SR 99 Ramp intersections. Therefore, these intersections were analyzed at a threshold level of service of LOS E.

Technical Analysis Parameters and Assumptions

This section presents the technical parameters assumed for the evaluation of the study intersections for the analysis scenarios. All parameters not listed should be assumed as default or calculated values based on HCM methodology.

Table A.2 Technical Parameter Assumptions

Technical Parameters	Assumption
1. Intersection Peak Hour Factor (PHF)	Intersection Overall, based on Existing Counts
2. Intersection Heavy Vehicle Percentage	Intersection Overall, based on Existing Counts, min. 2%
3. Signal Timings	Based on current Caltrans signal timing plans
4. Grades	2% or less at all intersections

Warrant Analysis

A supplemental traffic signal "warrant" analysis was completed for unsignalized intersections determined to be operating at an unacceptable LOS. The term "signal warrant" refers to the list of established criteria used by public agencies to quantitatively justify or ascertain the need for installation of a traffic signal at an unsignalized intersection. This study has employed the signal warrant criteria presented in the latest edition of the California Manual on Uniform Traffic Control Devices (MUTCD) for all unsignalized study intersection.

The California MUTCD indicates that the installation of a traffic signal should be considered if one or more of the signal warrants are met. Specifically, this study utilizes the peak hour volume-based Warrant 3 as one representative type of traffic signal warrant analysis. It should be noted that the Peak Hour Volume Warrant was only applied when the intersection was found to be operating at an unacceptable LOS. Therefore, there may be instances when the unsignalized intersection operates at acceptable LOS conditions but still meets the Peak Hour Volume Warrant.

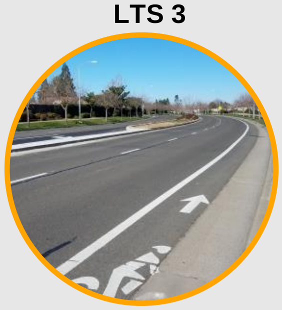
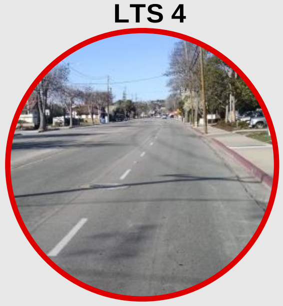
Bicycle Level of Traffic Stress (LTS) Methodology

The standardized methods used for the Bicycle Level of Traffic Stress (LTS) Analysis were adapted from the 2016 Oregon Department of Transportation (ODOT) *Analysis Procedure Manual, Version 2*. The original methodology can be obtained from the paper, "Low Stress Bicycling and Network Connectivity", Mineta Transportation Institute, Report 11-19, May 2012. Bicycle LTS is generally a perception-based rating system of the safety, comfort, and convenience of transportation facilities from the perspective of the user. The approach outlined in the ODOT manual uses roadway network data, including the posted speed limit, number of travel lanes, and presence and character of bicycle lanes as a proxy for bicyclist comfort level in urban context, and ADT and shoulder or bike lane width in rural settings. The Bicycle LTS methodology breaks road segments into one of four classifications or ratings for measuring the effects of traffic-based stress on bicycle riders, with 1 being the lowest stress or most comfortable, and 4 being the highest stress or least comfortable.

LTS 1 is assigned to roads that would be suitable for most children to ride, and to multi-use paths that are separated from motorized traffic. LTS 2 is assigned to roads that could be comfortably ridden by the average adult population. LTS 3 is the level assigned to roads that would be acceptable to current "enthused and confident" cyclists while LTS 4 is assigned to segments that are only acceptable to "strong and fearless" bicyclists, who will tolerate riding on roadways with higher motor traffic volumes and speeds. Further separation generally means less stress for users. Examples and descriptions for each level of traffic stress are presented in Table A.3.

The Bicycle LTS methodology is broken into three categories: segments (along), intersection approaches (turn lanes), and intersection crossings (unsignalized). Table-based criteria are applied separately for each category. Depending on the community context and the detail level desired, the overall methodology can usually be simplified based on the general consistency of facility types, as certain elements (i.e. no turn lanes, no bike lanes, limited speeds, etc.) may not exist in a particular community. If there are no turn lanes on an approach, then this portion of the methodology is skipped. Signalized intersections do not receive an LTS score. Signalized crossings usually do not create a barrier as the signal provides a protected way across and are not considered in the methodology.

Table A.3 Bicycle Level of Traffic Stress (LTS) Criteria

LTS Score	Description
LTS 1  Comfortable for all ages and abilities	Represents little traffic stress and requires less attention, so is suitable for all cyclists. This includes children that are trained to safely cross intersections (around 10 yrs. old/5th grade) alone and supervising riding parents of younger children. Generally, the age of 10 is the earliest age that children can adequately understand traffic and make safe decisions which is also the reason that many youth bike safety programs target this age level. Traffic speeds are low and there is no more than one lane in each direction. Intersections are easy to cross by children and adults. Typical locations include residential local streets and separated bike paths/cycle tracks.
LTS 2  Comfortable for most adults	Represents little traffic stress but requires more attention than young children can handle, so is suitable for teen and adult cyclists with adequate bike handling skills. Traffic speeds are slightly higher but speed differentials are still low and roadways can be up to three lanes wide in total for both directions. Intersections are not difficult to cross for most teenagers and adults. Typical locations include collector-level streets with bike lanes or a central business district.
LTS 3  Comfortable for confident bicyclists	Represents moderate stress and suitable for most observant adult cyclists. Traffic speeds are moderate but can be on roadways up to five lanes wide in both directions. Intersections are still perceived to be safe by most adults. Typical locations include low-speed arterials with bike lanes or moderate speed non-multilane roadways.
LTS 4  Uncomfortable for most	Represents high stress and suitable for experienced and skilled cyclists. Traffic speeds are moderate to high and can be on roadways from two to over five lanes wide in both directions. Intersections can be complex, wide, and or high volume/speed that can be perceived as unsafe by adults and are difficult to cross. Typical locations include high speed or multilane roadways with narrow or no bike lanes.

Source: "Low Stress Bicycling and Network Connectivity", Mineta Transportation Institute, Report 11-19, May 2012.

All roadways received a segment score. However, not all roadways received an approach or intersection crossing score. For example, a midblock portion of a street link received a segment score, but because it does not intersect another street, nor does it have turn lanes, neither an intersection nor approach score was assigned. The methodology uses the worst overall LTS value of each LTS category. For example, if a segment has a LTS 2 but there is an intersection approach at the end of the segment at LTS 4, then the whole segment is considered at LTS 4. The same applies for entire routes, which are typically reported in a single direction between two points of interest and can contain many segments and intersections. It is likely that the LTS will be different (i.e. right turn lane vs. left turn lane) in the two directions, so both directions should be reported.

Table A.4 and Table A.5 present the scoring criteria for segments, Table A.6 and Table A.7 present the scoring criteria for approaches, and Table A.8 and Table A.9 present the scoring criteria for crossing intersections. All tables are directly sourced from the ODOT *Analysis Procedure Manual*, Version 2, 2016. Additionally, only those tables from the ODOT manual that are applicable to the unique geometry of Carillion Boulevard are presented within this report.

Table A.4 Segment Criteria – Bike Lane Without Adjacent Parking Lane

	1 Lane per Direction				≥ 2 Lanes per Direction	
Prevailing or Posted Speed Limit (mph)	≥ 7' (Buffered bike lane)	5.5 – 7' Bike lane	≤ 5.5' Bike lane	Frequent bike lane blockage[1]	≥ 7' (Buffered bike lane)	< 7' Bike lane or frequent blockage[1]
≤ 30	LTS 1	LTS 1	LTS 2	LTS 3	LTS 1	LTS 3
35	LTS 2	LTS 3	LTS 3	LTS 3	LTS 2	LTS 3
≥ 40	LTS 3	LTS 4	LTS 4	LTS 4	LTS 3	LTS 4

1 Typically occurs in urban areas (i.e. delivery trucks, parking maneuvers, stopped buses).

Table A.5 Urban/Suburban Segment Criteria – Mixed Traffic

Prevailing or Posted Speed Limit (mph)	Unmarked Centerline	1 Lane per Direction	2 Lanes per Direction	3+ Lanes per Direction
≤ 25[1]	LTS 1	LTS 2	LTS 3	LTS 4
35	LTS 2	LTS 3	LTS 4	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4	LTS 4

1 Presence of "sharrow" markings may reduce the LTS by a level for 25 mph or less sections depending on overall area context.

Table A.6 Approach Criteria – Right Turn Lane

Right-turn lane configuration	Right-turn lane length (ft)	Bike Lane Approach Alignment[2]	Vehicle Turning Speed (mph)[3]	LTS
Single	≤ 150	Straight	≤ 15	2
Single	>150	Straight	≤ 20	3
Single	Any	Left	≤ 15	3
Single[1] or Dual Exclusive/ Shared	Any	Any	Any	4

1 Any other single right turn lane configuration not shown above.
2 The right turn criteria are based on whether the bike lane stays straight or shifts to the left.
3 This is vehicle speed at the corner, not the speed crossing the bike lane. Corner radius can also be used as a proxy for turning speeds.

Table A.7 Approach Criteria – Left Turn Lane

Left Turn Lane Criteria Prevailing Speed or Speed Limit (mph)	No lane crossed1	1 lane crossed	2+ lanes crossed	Dual shared or exclusive left turn lane2
≤25	LTS 2	LTS 2	LTS 3	LTS 4
30	LTS 2	LTS 3	LTS 4	LTS 4
≥ 35	LTS 3	LTS 4	LTS 4	LTS 4

1 For shared through left lanes or where mixed traffic conditions occur (no bike lanes)
2 Any other single left turn lane configuration not shown above.

Table A.8 Intersection Crossing Without a Median Refuge[1]

Prevailing or Posted Speed Limit (mph)	Total Lanes Crossed (Both Directions)		
	≤ 3 Lanes	4 -5 Lanes	≥ 6 Lanes
≤ 25	LTS 1	LTS 2	LTS 4
30	LTS 1	LTS 2	LTS 4
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

[1] For street being crossed.

Table A.9 Intersection Crossing With a Median Refuge[1]

Prevailing or Posted Speed Limit (mph)	Maximum Through/Turn Lanes Crossed per Direction		
	1-2 Lanes	2-3 Lanes	4+ Lanes
≤ 25	LTS 1	LTS 1	LTS 2
30	LTS 1	LTS 2	LTS 3
35	LTS 2	LTS 3	LTS 4
≥ 40	LTS 3	LTS 4	LTS 4

[1] For street being crossed.

[2] Refuge should be at least 10 feet to accommodate a wide range of bicyclists (i.e. bicycle with a trailer) for LTS 1, otherwise LTS=2 for refuges 6 to <10 feet.